Lawrence Livermore National Laboratory

PROGRAM UPDATE - NOVEMBER 2001

Laser Science & Technology

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UCRL-TB-136126-01-11

42-kW Diode Array Delivered to the HELSTF Program

Under the support of the U.S. Army's Space and Missile Defense Command, LS&T recently completed the fabrication of a 42-kW–peak-power laser-diode array for pumping of high-average–power solid-state heat-capacity laser for applications in tactical short-range air defense missions. Figure 1 shows the laser-diode module, which is constructed from 280 edge-emitting laser-diodes mounted on a backplane packaged by 28 closely packed **Si**licon **M**onolithic **M**icrochannel**s** tiles (SiMMs) arranged in 4 × 7 configuration. This pump module is designed to deliver 42 kW of 808-nm radiation when operated at 200 Hz or higher duty cycles.

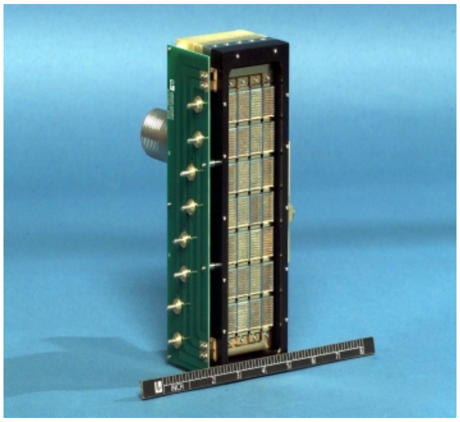

Figure 1. A 100 kW-class diode array module developed for pumping of high-average–power solid-state lasers.

The production of high-average–power by laser-diode arrays on the scale demonstrated here has relied on the development of a silicon-based diode packaging technology that has been actively pursued at LLNL for the last 15 years. The silicon package that serves to cool the laser-diode bars is produced by photolithography and etching techniques used in the microelectronic industry. Using this technology, we were able to manufacture thousands of miniscule 30-µm-wide channels in silicon substrates. Water flowing through these microchannels effectively cools the laser diode bars, which are mounted on the silicon at a location less than 200 µm from the channels. By mounting 10 diode bars onto a single heatsink, a 10-bar package (referenced as a tile and shown in Figure 2, top photograph) can be easily assembled to serve as a unit cell from which larger 2D diode arrays can be built up through tiling. Noteworthy in this design is that the brightness of the array is extremely high (presently 1 kW/cm^2 at a 10% duty factor), due to the compact tiling of the heatsinks and the precision placement of 10-element microlens arrays on each tile. The microchannel cooling technique allows higher duty factor operation if required by future systems.

Over the years, we have developed several types of diode packaging technologies for high-power applications. Special considerations were given to both the ease of fabrication and power scalability. In the current SiMMs design, we were able to preserve the same effective heat removal capability that characterized our original rack-and-stack silicon microchannel-cooled package by incorporating microchannels into the silicon directly below the attached laser-diode bars.

In order to fully utilize the light emitted from laser-diode bars (particularly along the fast axis that has a 30° divergence angle), we have also designed microlenses to collect radiation along the fast axis. A single-step microlens-mounting technique was developed to eliminate the production steps necessary to individually attach microlenses to each diode bar, dramatically reducing package cost. To achieve good optical performance, microlenses must be placed with a positional tolerance of a few microns relative to the diode bar emitter facets, and individual diode bars within a tile must also be positioned relative to one another with at least this same few-micron accuracy.

Using a V-groove technology on the front surface of the package accomplishes precision placement of the laser-diode bars. V-grooves are generated using the same etching technology that is used to fabricate the microchannels in silicon and serve as pads to which the laser diode bars are attached and precisely registered. Because the V-grooves are defined lithographically, output facets of individual bars can be located with micron precision relative to one another over the entire SiMMs tile. Single-step microlens mounting is accomplished using precision frames fabricated in the form of silicon runners. Lenses are preloaded and glued into these silicon runners forming a ladder-like structure consisting of 10 lenses as shown in Figure 2. These microlenses have effectively reduced the beam divergence of the array to <1 degree.

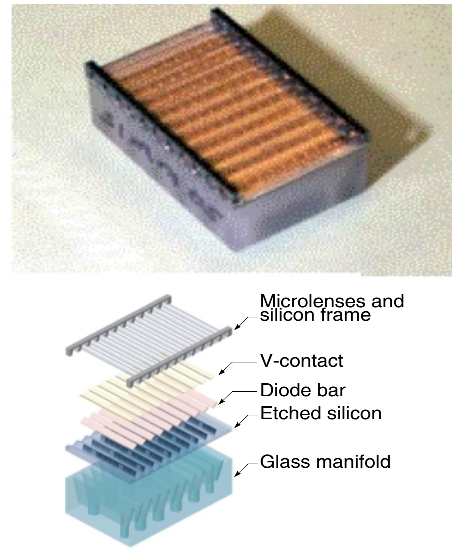

Figure 2. The SiMMs package. Top: Photograph of an individual SiMMs package. Bottom: Assembly drawing showing the various SiMMs package components in an exploded view. The V-grooves on the front surface of the silicon enable us to precisely position the laser-diode bars and microlenses with micron precision.

Using diode bars procured from the Coherent Semiconductor Group, Santa Clara, CA, we successfully achieved 1.5 kW of output power from a single tile (10-bar SiMMs package) with wall plug efficiencies approaching 50%. We plan to optimize the optical performance of the 42-kW array module and demonstrate pumping of Nd:GGG slab laser in future experiments. The SiMMs package represents a breakthrough in high-power diode-array packaging technology enabling us to scale the output of 2D diode arrays to 100 kW or larger with extremely high brightness.

—Ray Beach and Barry Freitas

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This work was performed under the auspices of the U.S. Department of Energy by
University of California Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.